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Module 11

GRAPHICAL PEAK DISCHARGE METHOD (TR-55)

Urban Hydrology for Small Watersheds (TR-55)

NRCS publication Technical Release Number 55 (TR-55): Urban Hydrology for Small Watersheds, 2nd edition (June 1986)

See Resources Section for link to TR-55 manual Review!

Peak Discharge

TR-55 presents two methods for estimating peak discharge

Graphical Method

Provides:
peak discharge and runoff volume

Tabular Method

Provides:
peak discharge, runoff volume, and a runoff hydrograph

TR55 Graphical Peak Discharge Method

Peak Discharge Equation

$$q_p = q_u A_m Q F_p$$

q_p = peak discharge (cfs)

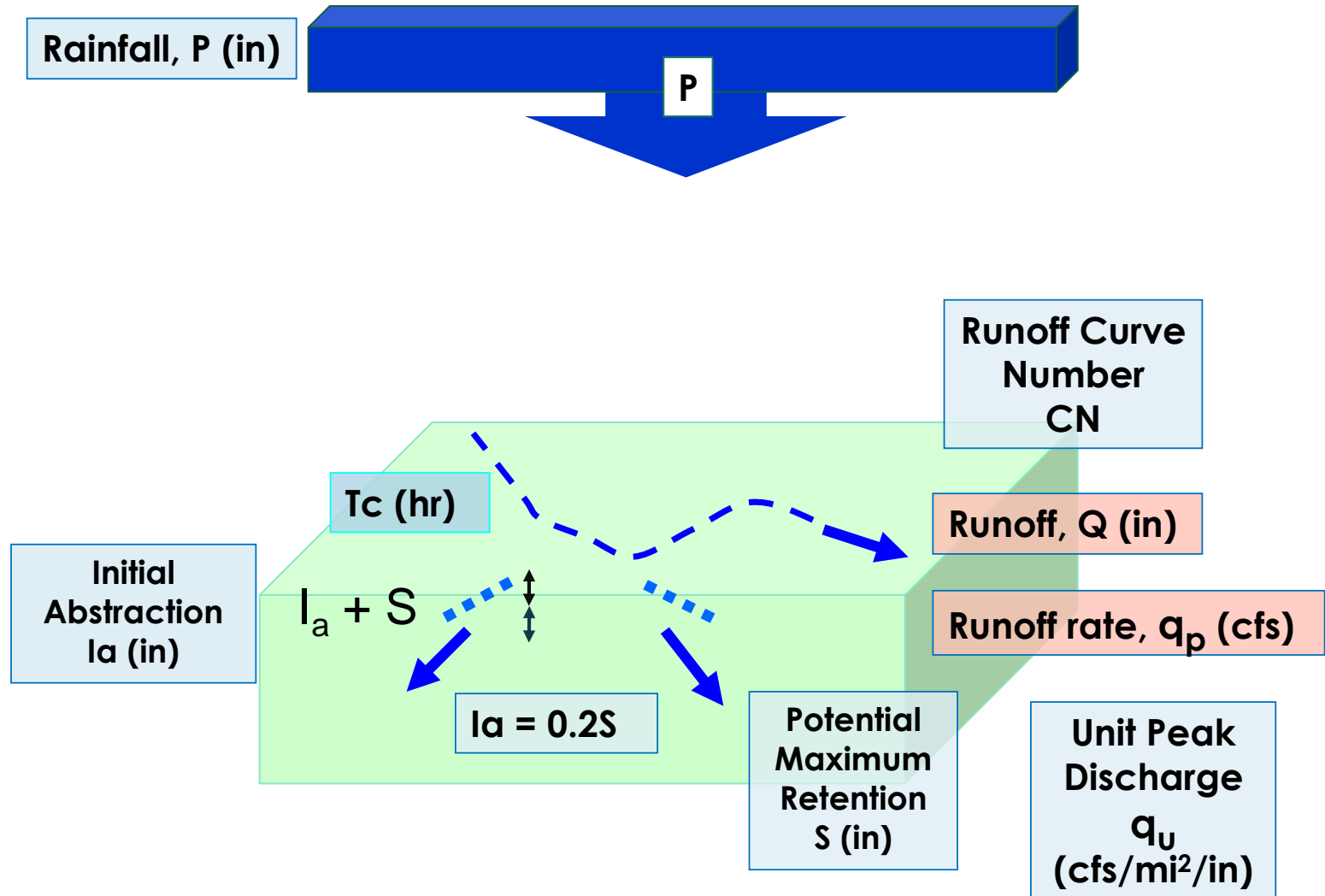
q_u = unit peak discharge (cfs/mi²-in; csm/in)

A_m = drainage area (mi²)

Q = runoff (in)

F_p = pond and swamp adjustment factor

- Example calculation given starting on **p.V-31 of VESCH**



TR55 Graphical Peak Discharge Method

Peak Discharge Equation

$$q_p = q_u A_m Q F_p$$

q_p = peak discharge (cfs)

q_u = unit peak discharge (cfs/mi²-in; csm/in)

A_m = drainage area (mi²)

Q = runoff (in)

F_p = pond and swamp adjustment factor

TR55 Graphical Peak Discharge Method

Peak Discharge Equation

$$q_p = q_u A_m QF_p$$

A_m = drainage area (mi²)

TR55 Graphical Peak Discharge Method

Peak Discharge Equation

$$q_p = q_u A_m Q F_p$$

F_p = pond and swamp adjustment factor

Look up in table (determine % swamp in DA)

TR55 Graphical Peak Discharge Method

Peak Discharge Equation

$$q_p = q_u A_m Q F_p$$

Q = runoff (in)

- 1 Calculate using Runoff Equation: P , I_a , S
- 2 Look up Q using CN (table or graph)

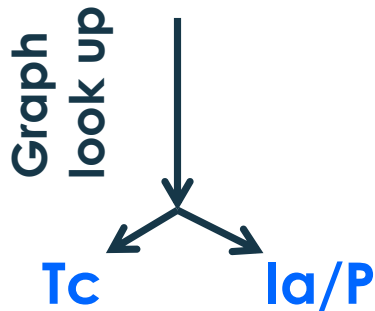
Calculate from CN
Or
Look up I_a and calculate S

TR55 Graphical Peak Discharge Method

Peak Discharge Equation

$$q_p = q_u A_m QF_p$$

q_u = unit peak discharge (cfs/mi²-in; csm/in)

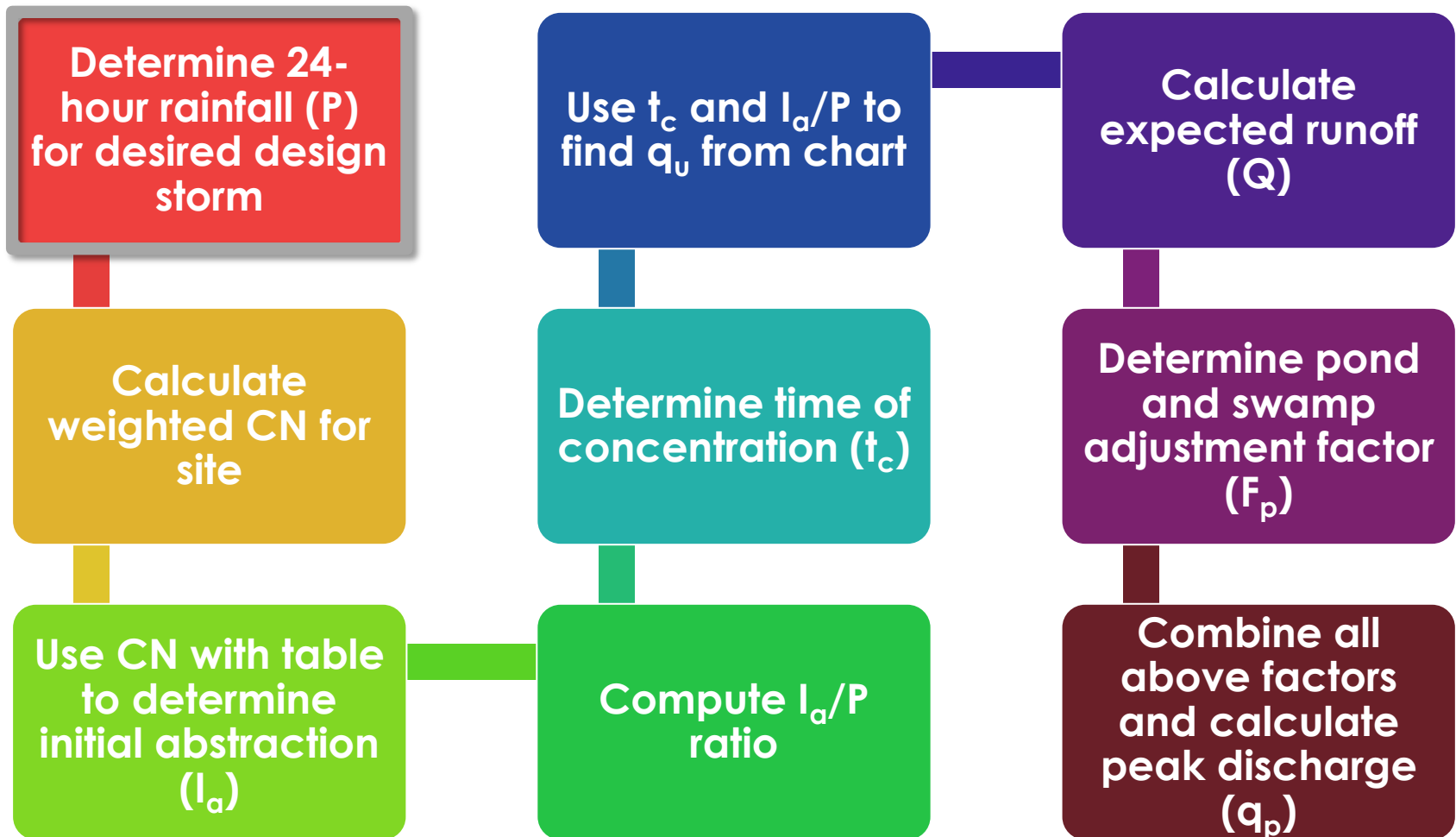


$$q_p = q_u A_m Q F_p$$

Information you will need -

- Drainage area, mi² (A_m)
- Rainfall distribution
(Type I, IA, II or III)
- Rainfall amount (P), inches
- Soil Hydrologic group
- Weighted runoff curve number (CN)
- Swamp Factor (F_p)
- Time of concentration (T_c), in hours ($\rightarrow q_u$)
- Total runoff (Q), inches
- Initial abstraction (I_a)
- Ratio of I_a/P

TR-55 Graphical Peak Discharge Method



Determine
rainfall

PG 7

- Precipitation
 - NOAA Atlas 14
 - Distribution

**Determine
rainfall**

NOAA Atlas 14, Volume 2, Version 3

Location name: Petersburg, Virginia, US*

Latitude: 37.1953°, Longitude: -77.3657°

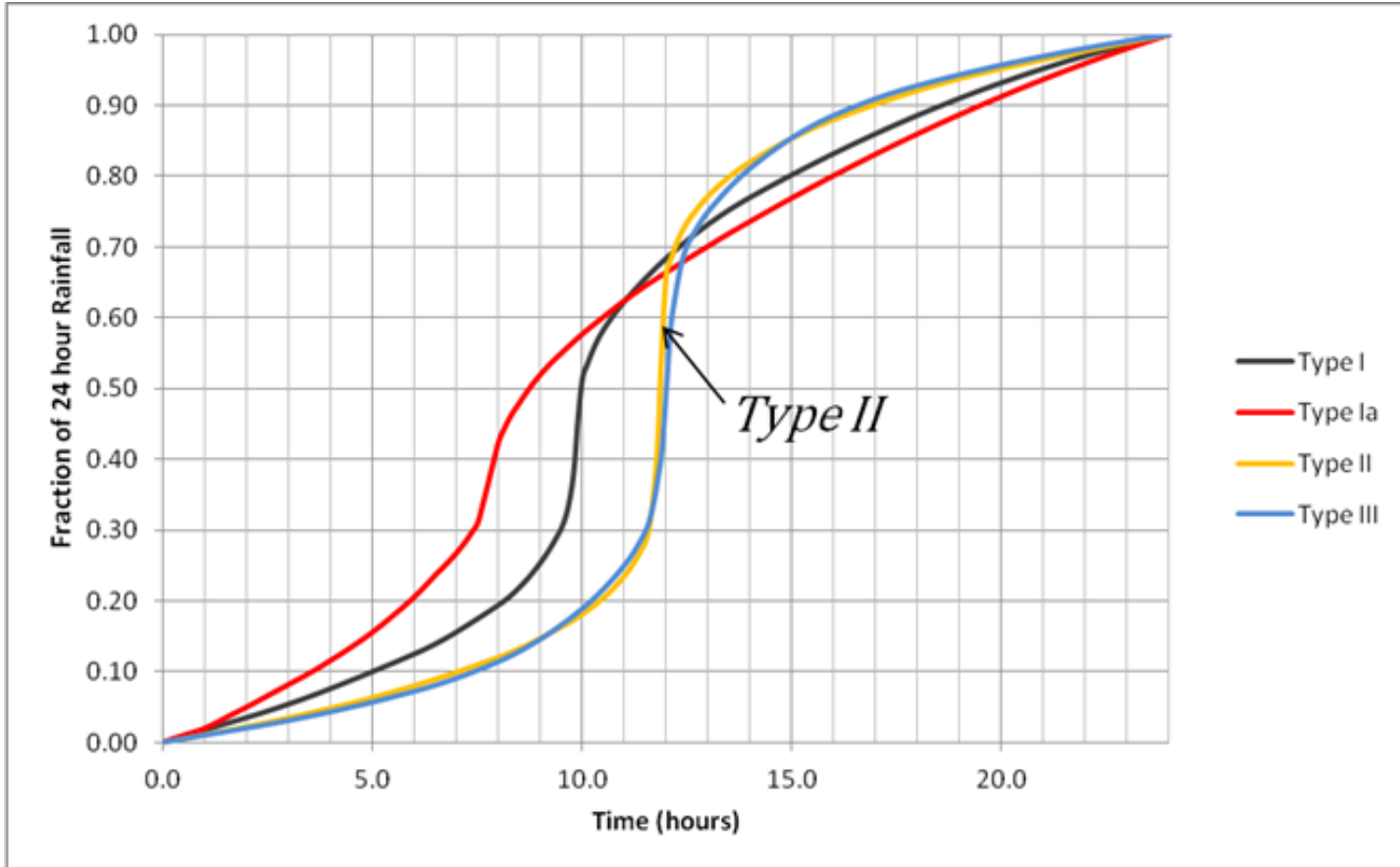


POINT PRECIPITATION FREQUENCY ESTIMATES

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches) ¹							
Duration	Average recurrence interval (years)						
	1	2	5	10	25	50	100
10-min	0.616 (0.553-0.689)	0.727 (0.654-0.810)	0.845 (0.760-0.941)	0.951 (0.853-1.06)	1.07 (0.951-1.18)	1.16 (1.03-1.29)	1.24 (1.10-1.38)
15-min	0.770 (0.691-0.861)	0.913 (0.822-1.02)	1.07 (0.961-1.19)	1.20 (1.08-1.34)	1.35 (1.21-1.50)	1.46 (1.30-1.63)	1.57 (1.39-1.74)
30-min	1.06 (0.948-1.18)	1.26 (1.14-1.41)	1.52 (1.37-1.69)	1.74 (1.56-1.94)	2.00 (1.79-2.22)	2.21 (1.96-2.45)	2.40 (2.12-2.67)
60-min	1.32 (1.18-1.47)	1.58 (1.43-1.76)	1.95 (1.75-2.17)	2.27 (2.04-2.53)	2.66 (2.38-2.96)	2.99 (2.66-3.32)	3.31 (2.93-3.67)
2-hr	1.57 (1.40-1.76)	1.89 (1.69-2.11)	2.34 (2.10-2.62)	2.76 (2.47-3.08)	3.30 (2.93-3.67)	3.76 (3.32-4.18)	4.22 (3.70-4.69)
3-hr	1.69 (1.50-1.90)	2.03 (1.81-2.28)	2.52 (2.26-2.83)	2.99 (2.66-3.35)	3.58 (3.17-4.01)	4.09 (3.60-4.58)	4.63 (4.04-5.16)
6-hr	2.03 (1.81-2.31)	2.44 (2.17-2.76)	3.04 (2.70-3.43)	3.61 (3.19-4.07)	4.36 (3.84-4.91)	5.03 (4.39-5.64)	5.72 (4.96-6.41)
12-hr	2.42 (2.16-2.76)	2.91 (2.60-3.30)	3.64 (3.24-4.12)	4.35 (3.85-4.91)	5.32 (4.67-5.98)	6.19 (5.39-6.94)	7.11 (6.14-7.96)
24-hr	2.80 (2.56-3.09)	3.40 (3.11-3.75)	4.36 (3.98-4.81)	5.17 (4.70-5.70)	6.35 (5.74-6.99)	7.36 (6.61-8.10)	8.46 (7.54-9.30)

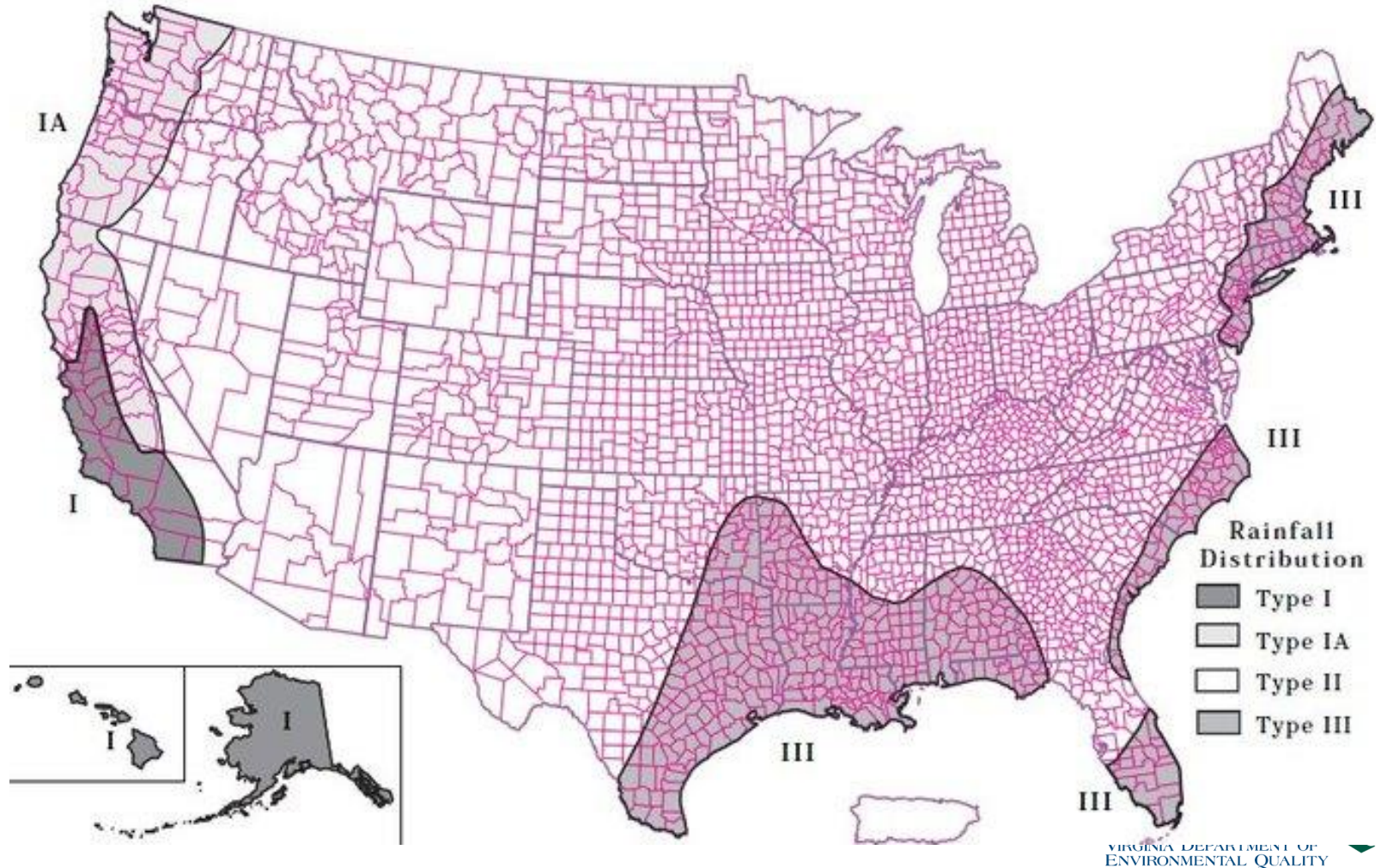
Determine
rainfall

Precipitation - Distribution



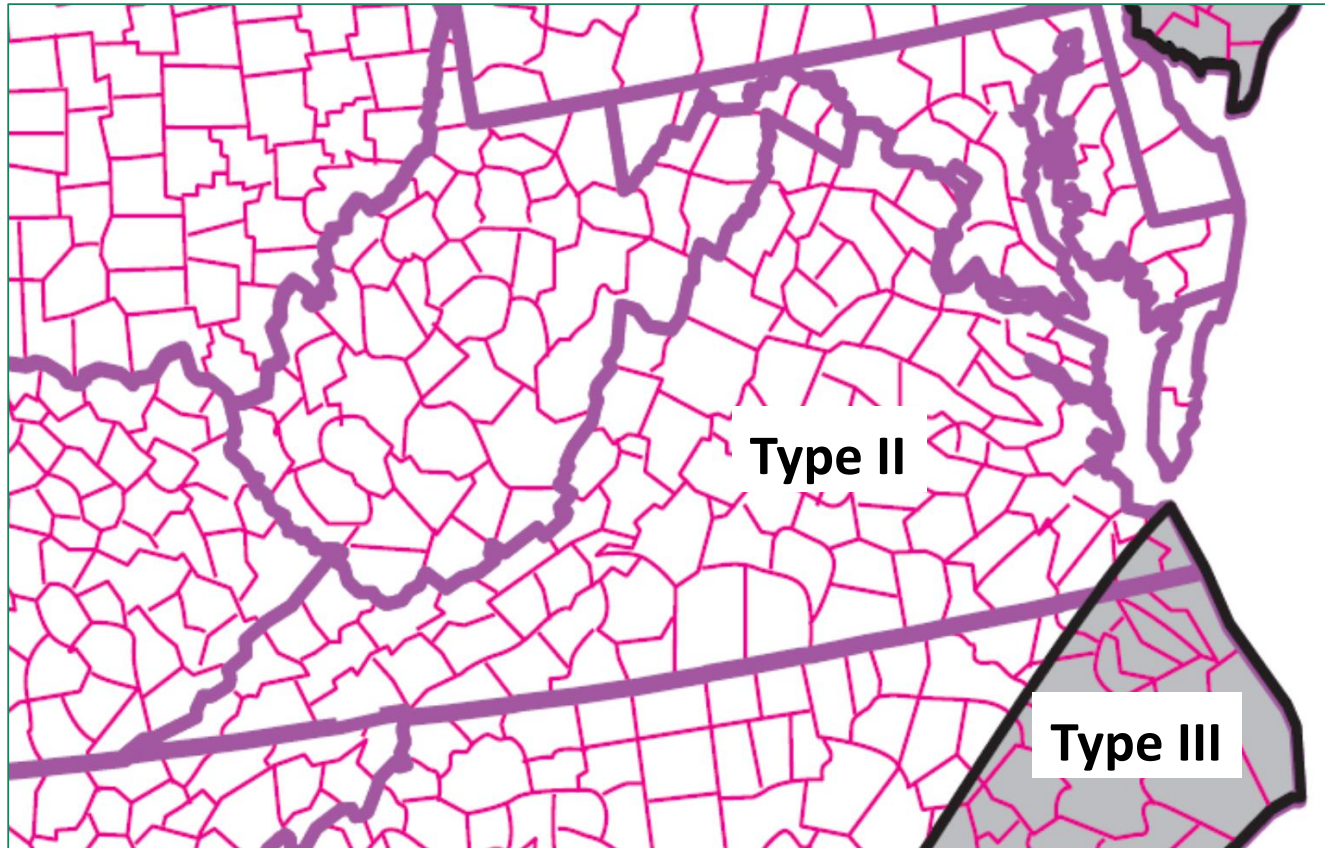
Determine
rainfall

Precipitation - Distribution



Determine
rainfall

Precipitation - Distribution



**Determine
rainfall**

$$q_p = q_u A_m Q F_p$$

- Use WinTR55 software

Storm Data

Roanoke County, VA (NRCS)

To replace these storm data with those compiled by the NRCS for Roanoke County, VA, click on the command button below.

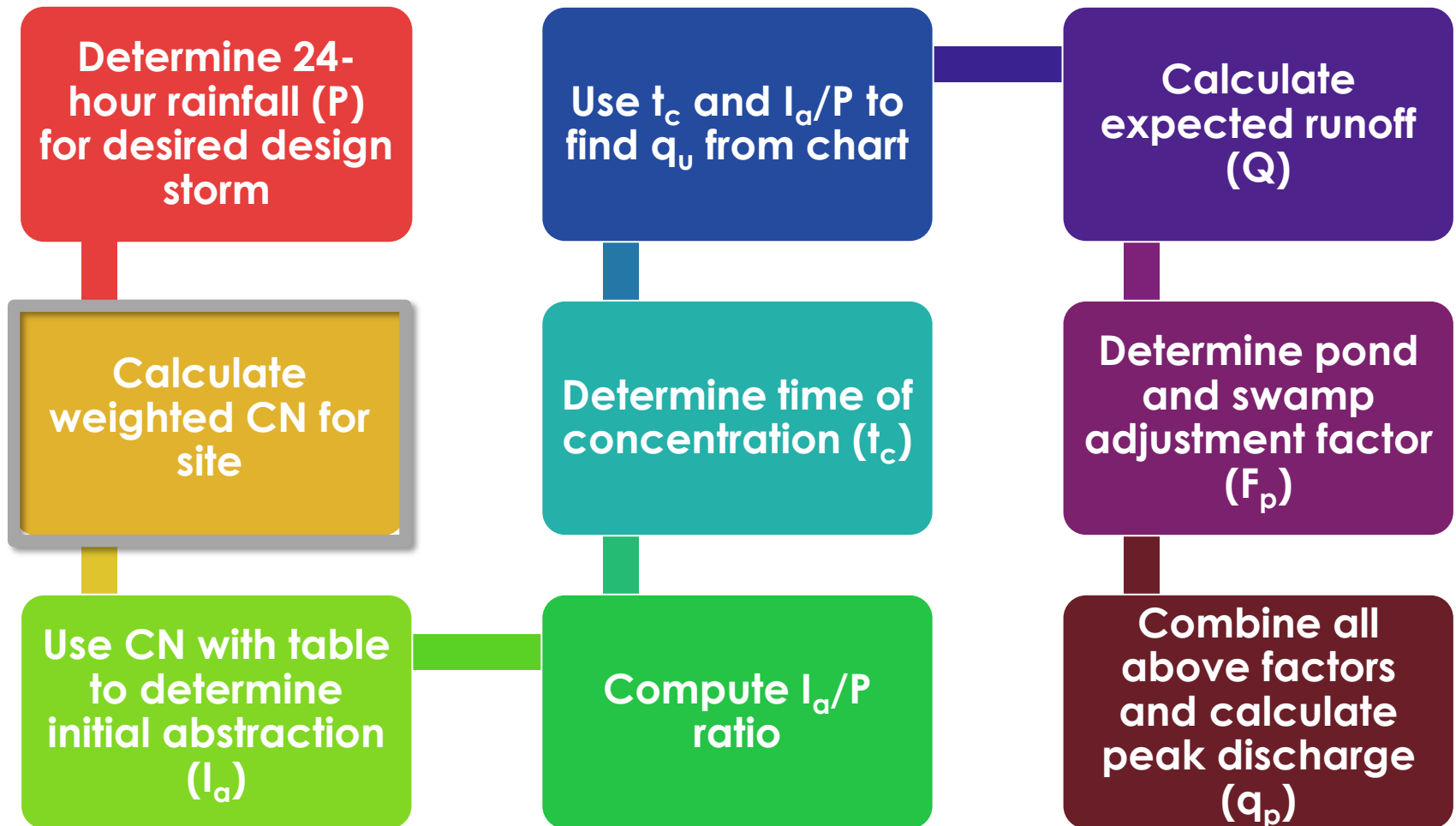
Please select a rainfall distribution type from the list below. The list includes the standard WinTR-20 / WinTR-55 types and any number of user-defined distributions.

Rainfall Distribution Type:

Rainfall Return Period (yr)	24-Hr Rainfall Amount (in)
2	3.5
5	4.5
10	5
25	6
50	6.5
100	7.5
1	3

File: <new file> 9/9/2008 3:54 AM

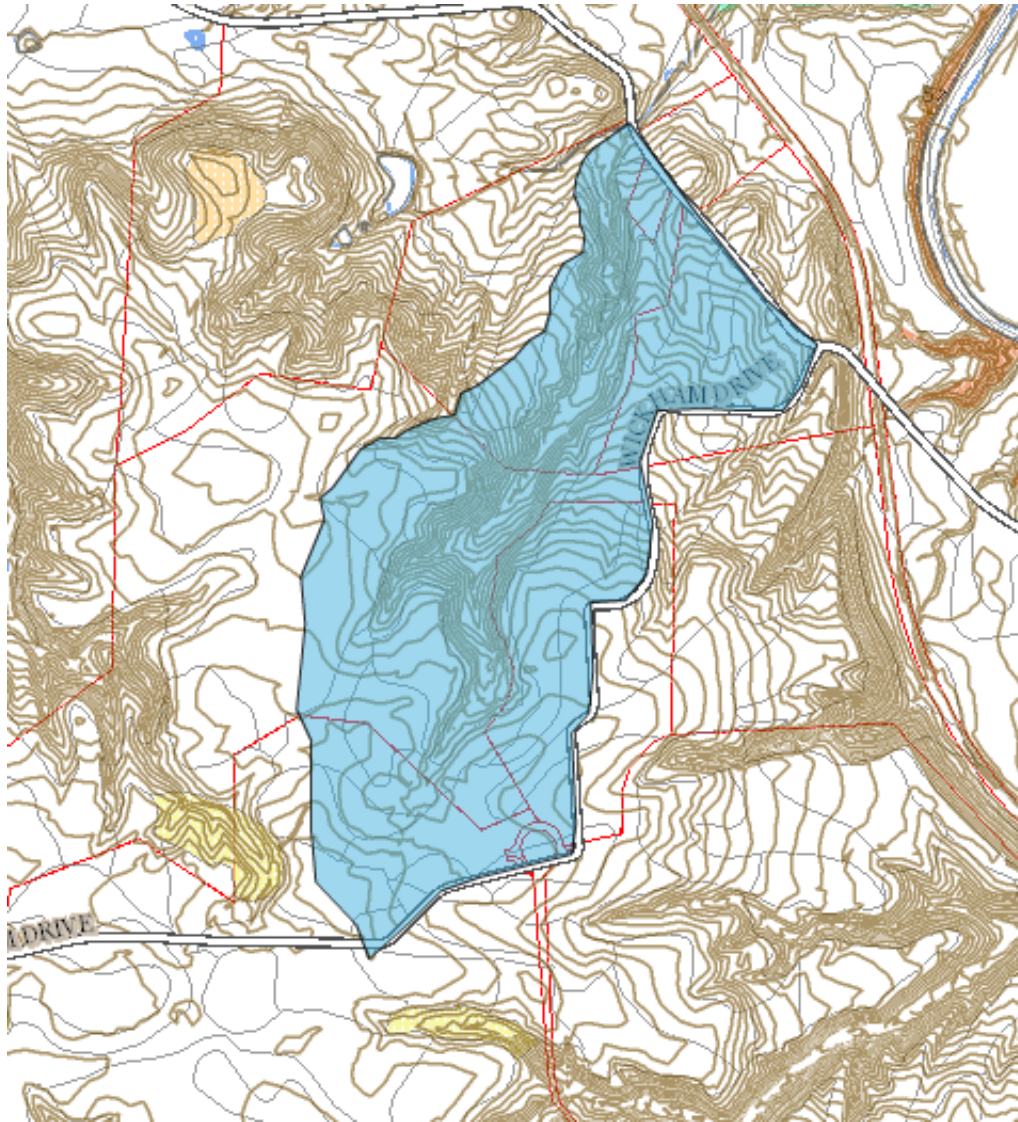
TR-55 Graphical Peak Discharge Method



weighted
CN

$$q_p = q_u A_m QF_p$$

CN indicates
runoff potential of an area



Watershed Delineation:

- Choose watershed outlet point
- Delineate watershed boundary (perpendicular lines across contour lines draining to point of interest)

Note - A watershed boundary always runs perpendicular to contour lines

weighted
CN

$$q_p = q_u A_m Q F_p$$

- Need Hydrologic Soil Group (HSG) for each of the soils at site and area of each soil type
- Soils information from:
 - Site drawings or E&S plan
 - NRCS Web Soil Survey
(<http://websoilsurvey.nrcs.usda.gov/app/>)
 - VESCH Appendix 6C
 - 1991 SWMHB Appendix 4A

weighted
CN

- CN determination:
 - Soils
 - Hydrologic conditions
 - (good, fair, poor)
 - Cover type
 - Treatment (sometimes)

weighted
CN

- CN determination:
 - 4 Curve Number Tables
 - Urban
 - Cover type-** vegetation, bare soil, and impervious surfaces.
 - cultivated agricultural lands
 - other agricultural lands
 - arid and semiarid rangelands

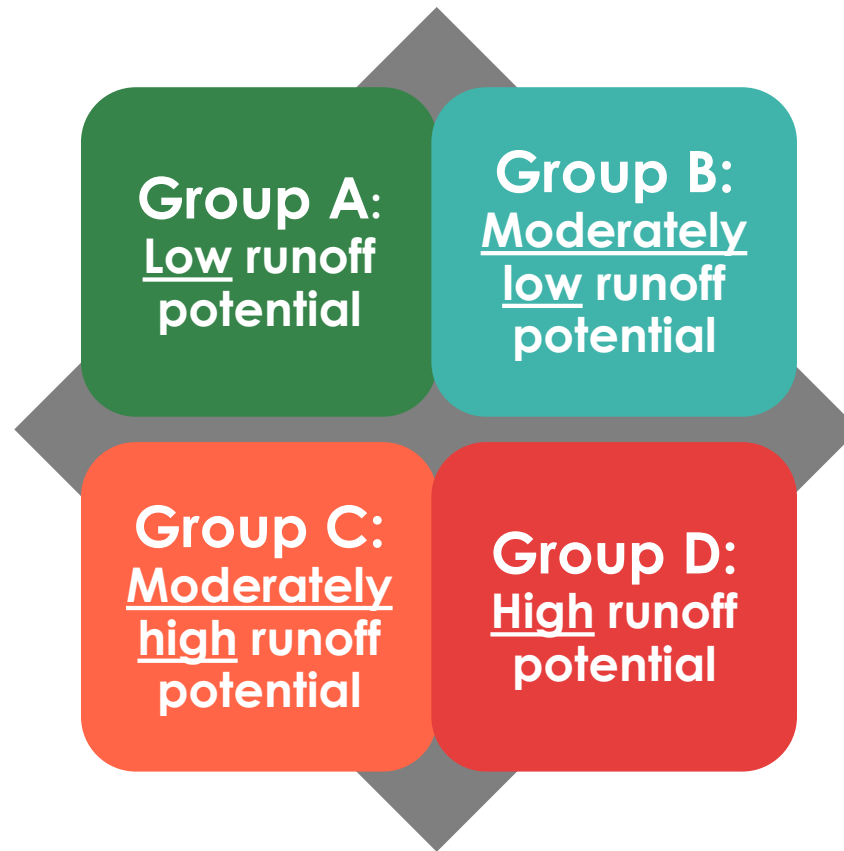
weighted
CN

- **Treatment** - cover type modifier for agricultural (contouring, terracing)
 - **For ag and arid/semiarid**



weighted
CN

Hydrologic Soil Groups



weighted
CN

Runoff curve numbers for urban areas ^{1/}

Table 11-2 Runoff CNs for Urban Areas

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area ^{2/}	A	B	C	D
<i>Fully developed urban areas (vegetation established)</i>					
Open space (lawns, parks, golf courses, cemeteries, etc.) ^{3/} :					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) ^{4/}		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82

weighted
CN

**Table 11-4 Runoff Curve Numbers for
Other Agricultural Lands**

Cover description	Hydrologic condition	Curve numbers for hydrologic soil group			
		A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. ^{2/}	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. ^{3/}	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 ^{4/}	48	65	73
Woods—grass combination (orchard or tree farm). ^{5/}	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. ^{6/}	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 ^{4/}	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

¹ Average runoff condition, and $I_a = 0.2S$.

² *Poor*: <50% ground cover or heavily grazed with no mulch.

Fair: 50 to 75% ground cover and not heavily grazed.

Good: > 75% ground cover and lightly or only occasionally grazed.

³ *Poor*: <50% ground cover.

Fair: 50 to 75% ground cover.

weighted
CN

$$q_p = q_u A_m Q F_p$$

TABLE 5-5*
RUNOFF CURVE NUMBERS
FOR GRAPHICAL PEAK DISCHARGE METHOD

COVER DESCRIPTION		HYDROLOGIC SOIL GROUP			
		A	B	C	D
Fully Developed Urban Areas (Vegetation Established)					
Open Space (lawns, parks, etc.)	Poor Condition; Grass	68	79	86	89
	Fair Condition; Grass 50 - 75% cover	49	69	79	84
	Good Condition; Grass > 75% cover	39	61	74	80
Impervious Areas	Paved parking lots, roofs, driveways	98	98	98	98
Streets and Roads	Paved; curbs and storm sewers	98	98	98	98
	Paved; open ditches (w/right-of- way)	83	89	92	93
	Gravel (with right-of-way)	76	85	89	91
	Dirt (with right-of-way)	72	82	87	89
Urban Districts		Average % Impervious			
	Commercial and Business	85	89	92	94
	Industrial	72	81	88	91

**VESCH, Table 5-5,
p. V-56 to -59**

and

TR-55 Manual

$$\mathbf{q}_p = \mathbf{q}_u \mathbf{A}_m \mathbf{Q} \mathbf{F}_p$$

- Calculate weighted average CN for site
- Example worksheet in **VESCH, p. V-46**

Worksheet 2: Runoff curve number and runoff

1992

Project Defiance Ridge By ESC Date 2-4-91
 Location Campbell County, Virginia Checked SNH Date 2-5-91
 Circle one: Present Developed D.A. 250 ac.

i. Runoff curve number (CN)

Soil name and hydrologic group	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	<u>CN 1/</u>			Area <u>800</u> acres <u>mi²</u>	Product of CN x area
		Table 5-5	Fig. 2-3	Fig. 2-4		
Appendix 6C						
Appling, B	1/2 Ac. Lots, Good Condition	70			40	2800
Appling, B	Commercial	92			10	920
Helena, C	1/2 Ac. Lots, Good Condition	80			30	2400
Helena, C	Open Space, Good Condition	74			20	1480
					Totals =	100 7600

1/ Use only one CN source per line.

CN (weighted) = $\frac{\text{total product}}{\text{total area}}$ = $\frac{7600}{100}$ = 76; Use CN = 76

Land Use Details

Subarea Name:

Land Use Categories

☒ Urban Area ☐ Developing Urban ☐ Cultivated Agriculture ☐ Other Agriculture ☐ Arid Rangeland

Area (Acres) for Hydrologic Soil Groups

Cover Description		A	CN	B	CN	C	CN	D	CN
1/8 acre (town houses)	65	77	20.000	95	95	95	95	95	95
1/4 acre	38	91	75	93	97	97	97	97	97
1/3 acre	30	87	72	98	91	98	98	98	98
1/2 acre	25	54	70	90	95	95	95	95	95
1 acre	20	51	68	79	94	94	94	94	94
2 acre	12	48	55	77	92	92	92	92	92

Western Desert Urban Areas

Natural desert (previous areas only)

Artificial desert land-scaping

User defined urban (Click button to define)

Project Area(ac) Summary Screen ☒ Off ☐ On Sub-Area Area (ac) Weighted CN:

weighted
CN

Exercise:

Determine a composite curve number given the following data:

24 acres - open space, soil c

16 acres - 1/2 acre lots, 25% impervious, good condition, soil b

18 acres - woods Soil D

Solution : $(24*74) + (16*70) + (18*77) =$

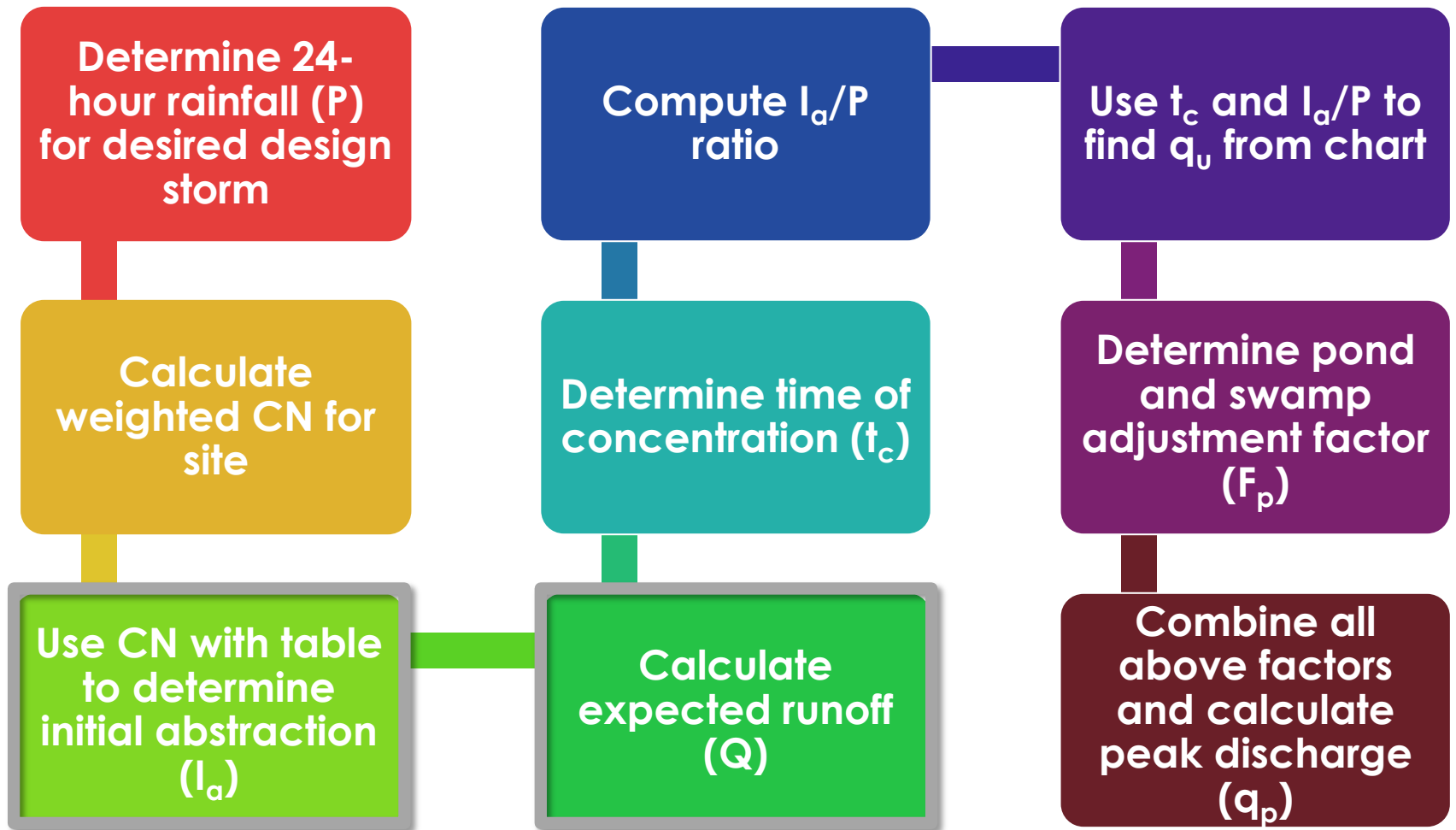
$1776 + 1120 + 1386 = 4282 / 58 = 73.8$ Round to 74

weighted
CN

Additional factors that can further adjust curve numbers

- Antecedent runoff condition
 - Index of runoff potential before a storm event
- **Urban impervious area modifications**
 - **Connected impervious areas**
 - Unconnected impervious

TR-55 Graphical Peak Discharge Method



initial
abstraction
(I_a)

$$q_p = q_u A_m Q F_p$$

- Look up I_a values in **VESCH Table 5-9, p. V-64** or TR-55 manual

TABLE 5-9

 I_a VALUES FOR RUNOFF CURVE NUMBERS

Curve Number	I_a (inches)	Curve Number	I_a (inches)	Curve Number	I_a (inches)
40	3.000	60	1.333	80	0.500
41	2.878	61	1.279	81	0.469
42	2.762	62	1.226	82	0.439
43	2.651	63	1.175	83	0.410
44	2.545	64	1.125	84	0.381
45	2.444	65	1.077	85	0.353
46	2.348	66	1.030	86	0.326
47	2.255	67	0.985	87	0.299
48	2.167	68	0.941	88	0.273
49	2.082	69	0.899	89	0.247
50	2.000	70	0.857	90	0.222
51	1.922	71	0.817	91	0.198
52	1.846	72	0.778	92	0.174
53	1.774	73	0.740	93	0.151
54	1.704	74	0.703	94	0.128
55	1.636	75	0.667	95	0.105
56	1.571	76	0.632	96	0.083
57	1.509	77	0.597	97	0.062
58	1.448	78	0.564	98	0.041
59	1.390	79	0.532		

initial
abstraction
(I_a)

Runoff
Volume
(Q)

$$q_p = q_u A_m Q F_p$$

- Solve for Q (runoff depth):
 - SCS Runoff equation
 - Tabular method, VESCH Table 5-6, p. V-60 and TR-55 Manual
 - Graphical method, TR-55 Manual

initial
abstraction
(I_a)

Runoff
Volume
(Q)

$$q_p = q_u A_m Q F_p$$

Runoff Equation

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Q = Runoff (in)

P = Rainfall (in)

S = Potential maximum retention after runoff begins (in)

$$S = \left(\frac{1000}{CN} \right) - 10$$

CN = Curve number

I_a = Initial abstraction (in)

= $0.2 \times S$

= (all losses before runoff begins)

$$q_p = q_u A_m Q F_p$$

Find Q
VESCH
Table 5-6,
p. V-60

TABLE 5-6
RUNOFF DEPTH FOR SELECTED CN's AND RAINFALL AMOUNTS¹

Runoff depth for curve number of ____

Rainfall	40	45	50	55	60	65	70	75	80	85	90	95	98
	<i>inches</i>												
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56	0.79
1.2	.00	.00	.00	.00	.00	.00	.00	.03	.07	.15	.27	.46	.99
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	.00	.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41	5.76
7.0	.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

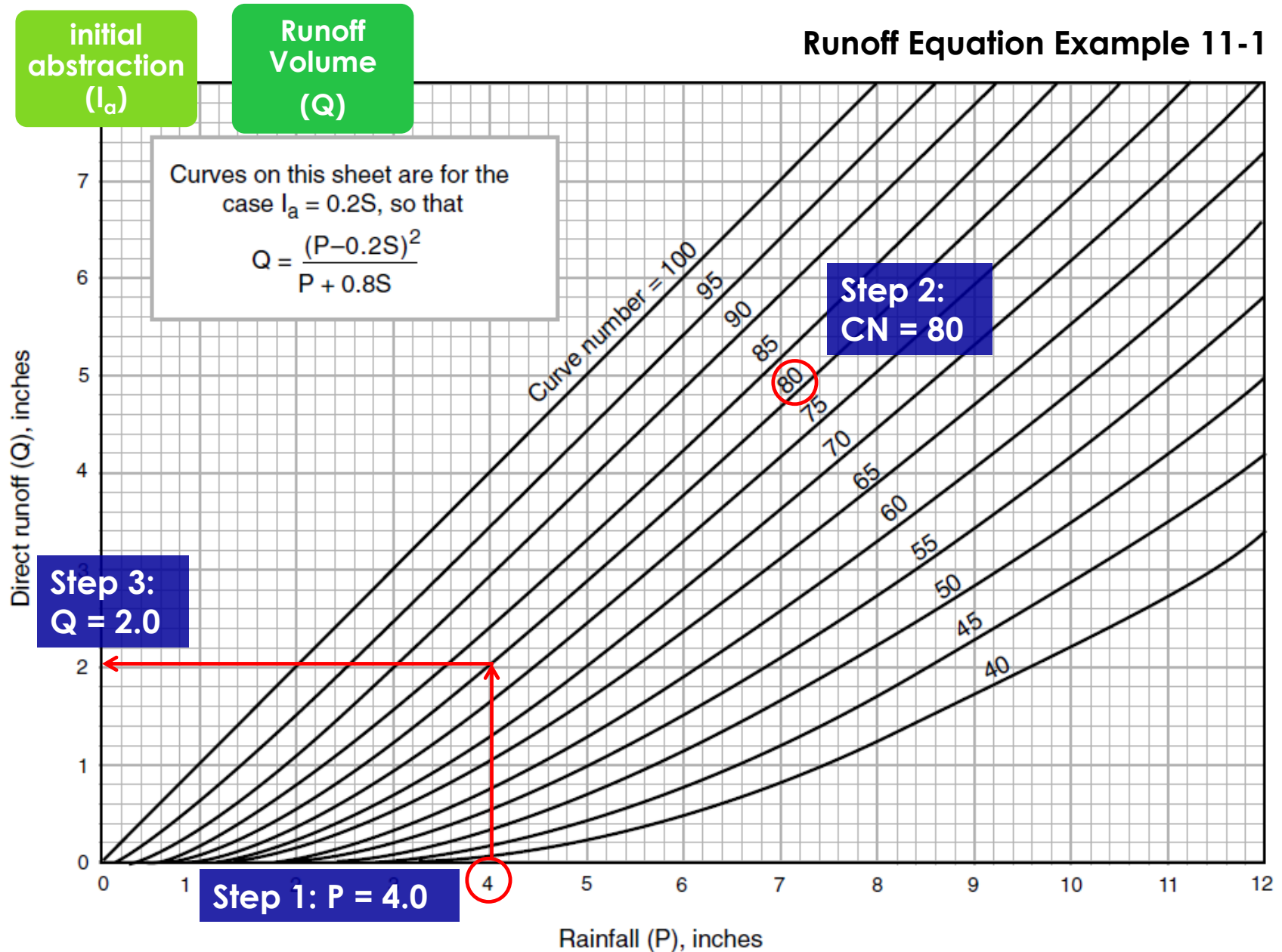
¹ Interpolate the values shown to obtain runoff depths for CN's or rainfall amounts not shown.

Runoff Equation Example 11-1

Given a watershed with a CN of 80, what would be the direct runoff (Q) from a rainfall (P) of 4.0 inches?

Runoff Equation Example 11-1													
initial abstraction (I_a)	Runoff Volume (Q)												
Runoff depth for curve number of—													
Rainfall	40	45	50	55	60	65	70	75	80	85	90	95	98
	inches												
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.15	0.32	0.56	0.79
1.2	.00	.00	.00	.00	.00	.00	.03	.07	.15	.24	.46	.74	.99
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	.00	.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.29	4.82	5.41	5.76
7.0	.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

Runoff Equation Example 11-1



Runoff
Volume
(Q)

Runoff Equation Example 11-1

P = rainfall (in)

CN = runoff curve number

S = potential maximum
retention after runoff
begins (in)

$$S = \left(\frac{1000}{CN} \right) - 10 = \left(\frac{1000}{80} \right) - 10 = 2.5$$

$$\begin{aligned} I_a &= \text{initial abstraction (in)} \\ &= 0.2 \times S \\ &= 0.2 \times 2.5 \\ &= 0.5 \end{aligned}$$

$$\begin{aligned} Q &= \frac{(P - I_a)^2}{(P - I_a) + S} \\ &= \frac{(4.0 - 0.5)^2}{(4.0 - 0.5) + 2.5} = 2.04 \end{aligned}$$

Runoff Exercise:

Given a watershed with a CN of 85, what would be the direct runoff (Q) from a rainfall (P) of 2.5 inches?

P = rainfall (in)

CN = runoff curve number

Runoff Equation Example 11-2

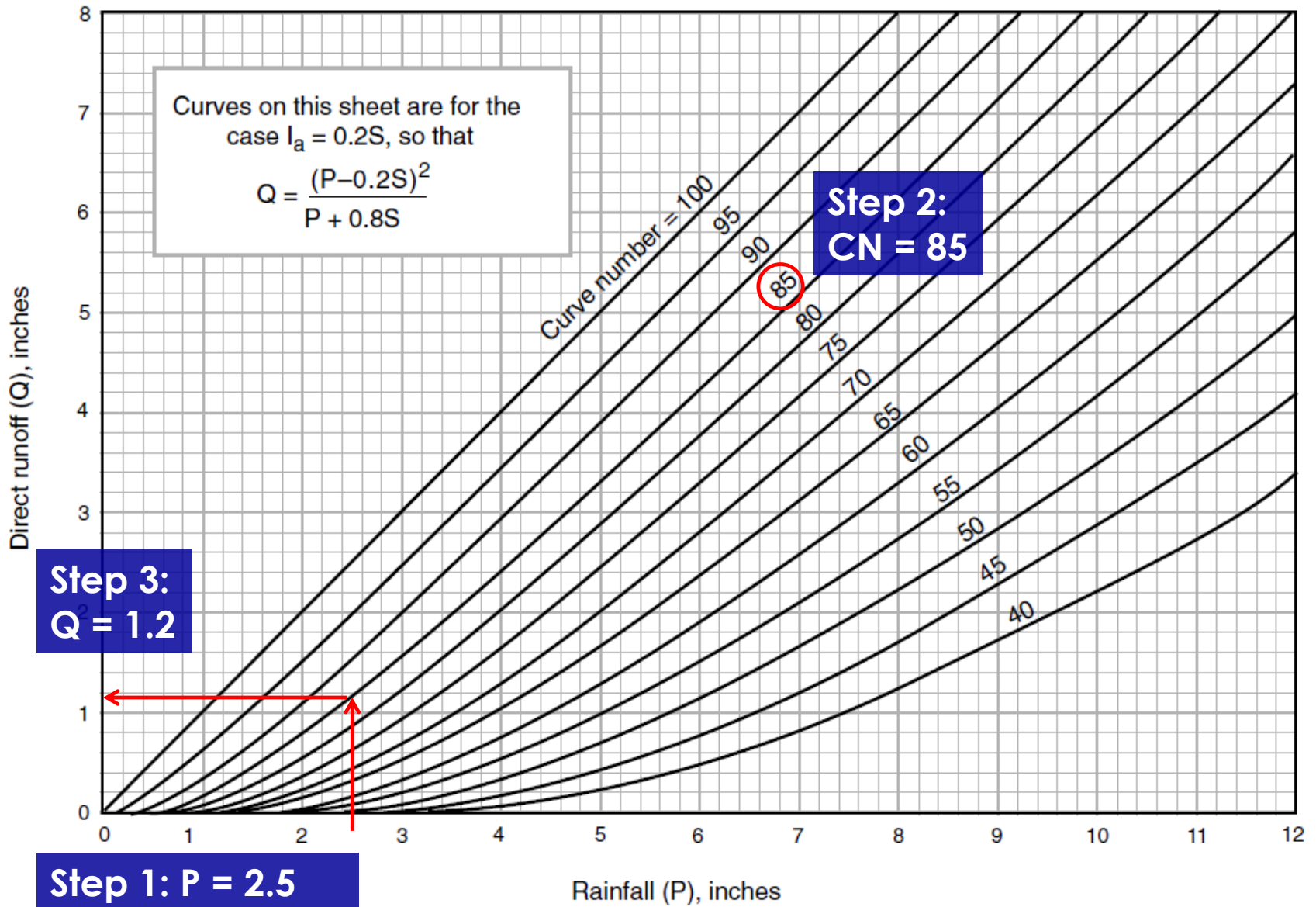
Rainfall	Runoff depth for curve number of—												
	40	45	50	55	60	65	70	75	80	85	90	95	98
	inches												
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56	0.79
1.2	.00	.00	.00	.00	.00	.00	.03	.07	.15	.27	.46	.74	.99
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.63	1.01	1.18
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	.06	.06	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.44	2.91	3.27
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.91	3.40	3.77
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
5.5	.36	.60	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.76
7.0	.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

Step 2:
CN = 85

Step 3:
Q = 1.18

Step 1:
P = 2.5

Runoff Equation Example 11-2



Runoff Equation Example 11-2

P = rainfall (in)

CN = runoff curve number

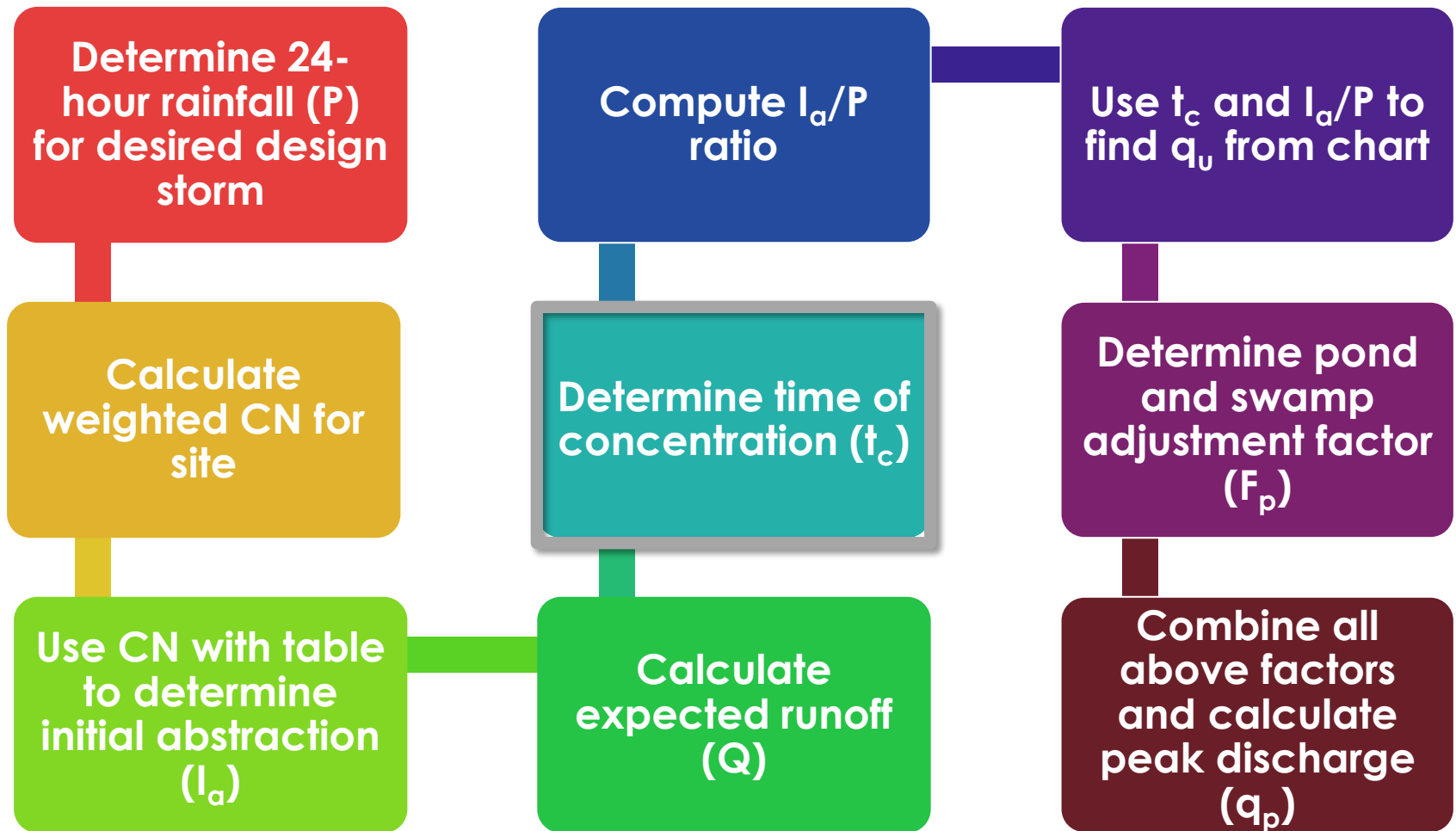
S = potential maximum retention after runoff begins (in)

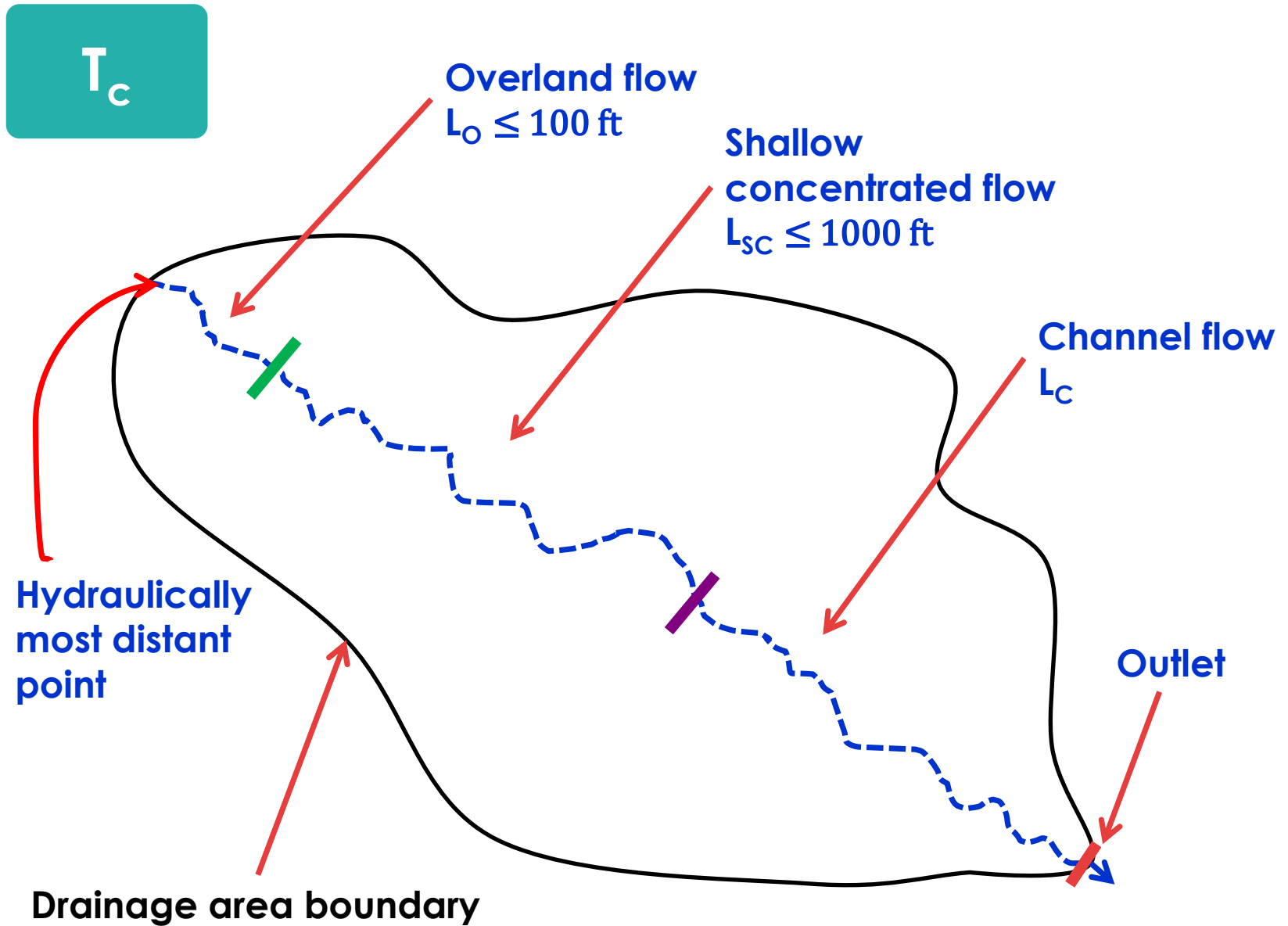
$$S = \left(\frac{1000}{CN} \right) - 10 = \left(\frac{1000}{85} \right) - 10 = 1.8$$

$$I_a = \text{initial abstraction (in)} = \mathbf{0.2 \times S = 0.2 \times 1.8 = 0.36}$$

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} = \frac{(2.5 - 0.36)^2}{(2.5 - 0.36) + 1.8} = 1.16$$

TR-55 Graphical Peak Discharge Method





T_c

Example worksheet on p. V-42 of VESCH

Time of Concentration Details

Subarea Name: Condos Bename Clear 2-Year Rainfall (in): 2.47

Flow Type	Length (ft)	Slope (ft/ft)	Surface (Manning's n)	n	Area (ft ²)	WP (ft)	Velocity (ft/s)	Time (hr)
Sheet	20	0.005	Grass-Range, Short (0.15)					0.089
Shallow Concentrated	100	0.005	Paved					0.019
Shallow Concentrated								
Channel	2000						5.000	0.111
Channel								
Total	2.120						2.6813	0.220

File: C:\Program Files\WinTR55\LICA Release Rate.v65 2/23/01 10:30 AM

$$q_p = q_u A_m Q F_p$$

Worksheet 3: Time of concentration (T_c) or travel time (T_t) 1992

Project Defiance Ridge By ESC Date 2-4-91
 Location Campbell County, Virginia Checked SWM Date 2-5-91

Circle one: Present Developed _____
 Circle one: T_c T_c through subarea _____

NOTES: Space for as many as two segments per flow type can be used for each worksheet.
 Include a map, schematic, or description of flow segments.

Sheet flow (Applicable to T_c only) Segment ID

Segment ID	AB	
1. Surface description (table 5-7)	Woods, lt. brush	
2. Manning's roughness coeff., n (table 5-7) ..	0.40	
3. Flow length, L (total L \leq 300 ft)	200	
4. Two-yr 24-hr rainfall, P_2 (worksheet 2) ...	3.5	
5. Land slope, s	0.02	
6. $T_c = \frac{0.007 (nL)^{0.8}}{P_2^{0.5} s^{0.4}}$ Compute T_c	0.60	0.60

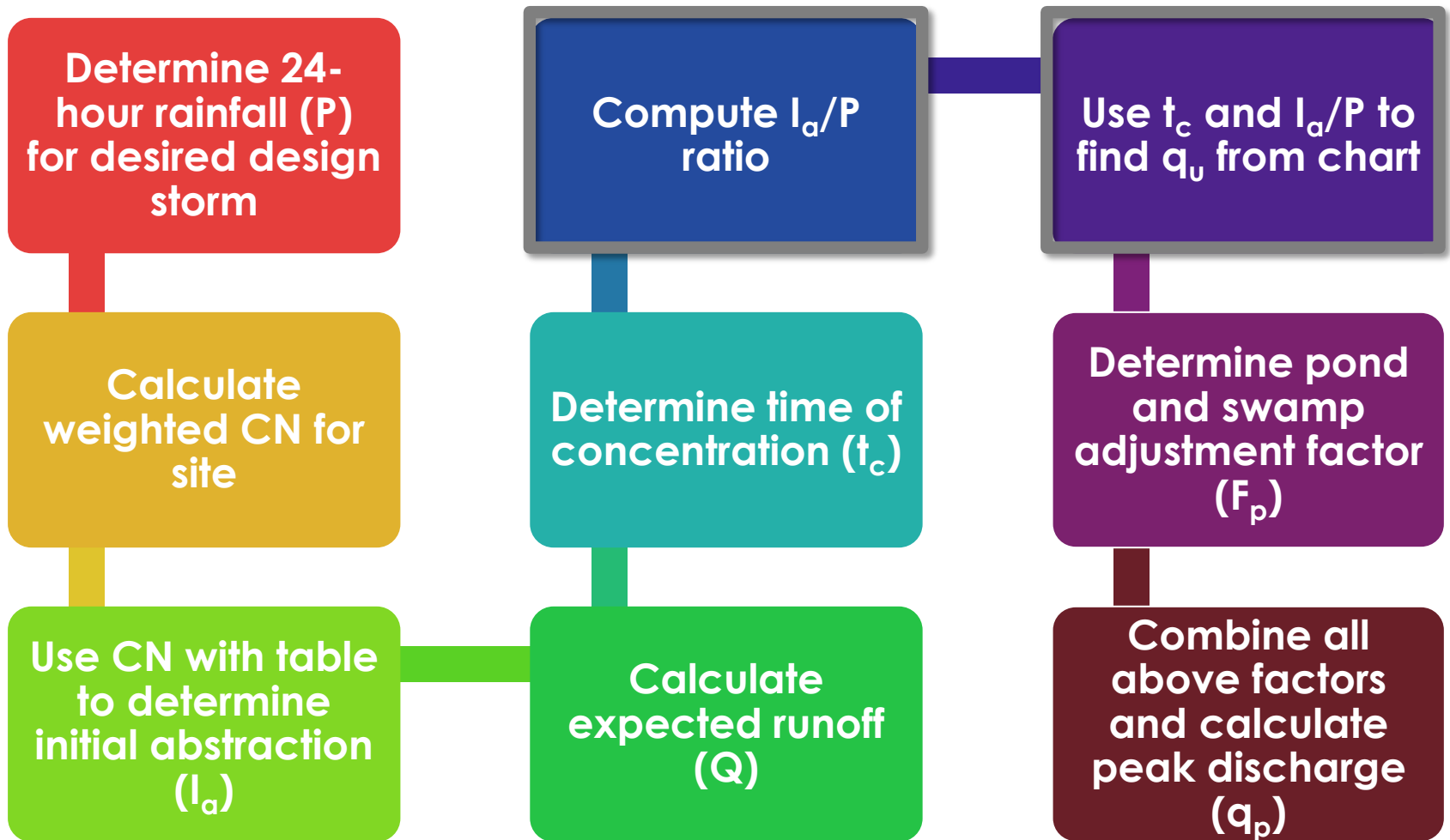
Shallow concentrated flow Segment ID

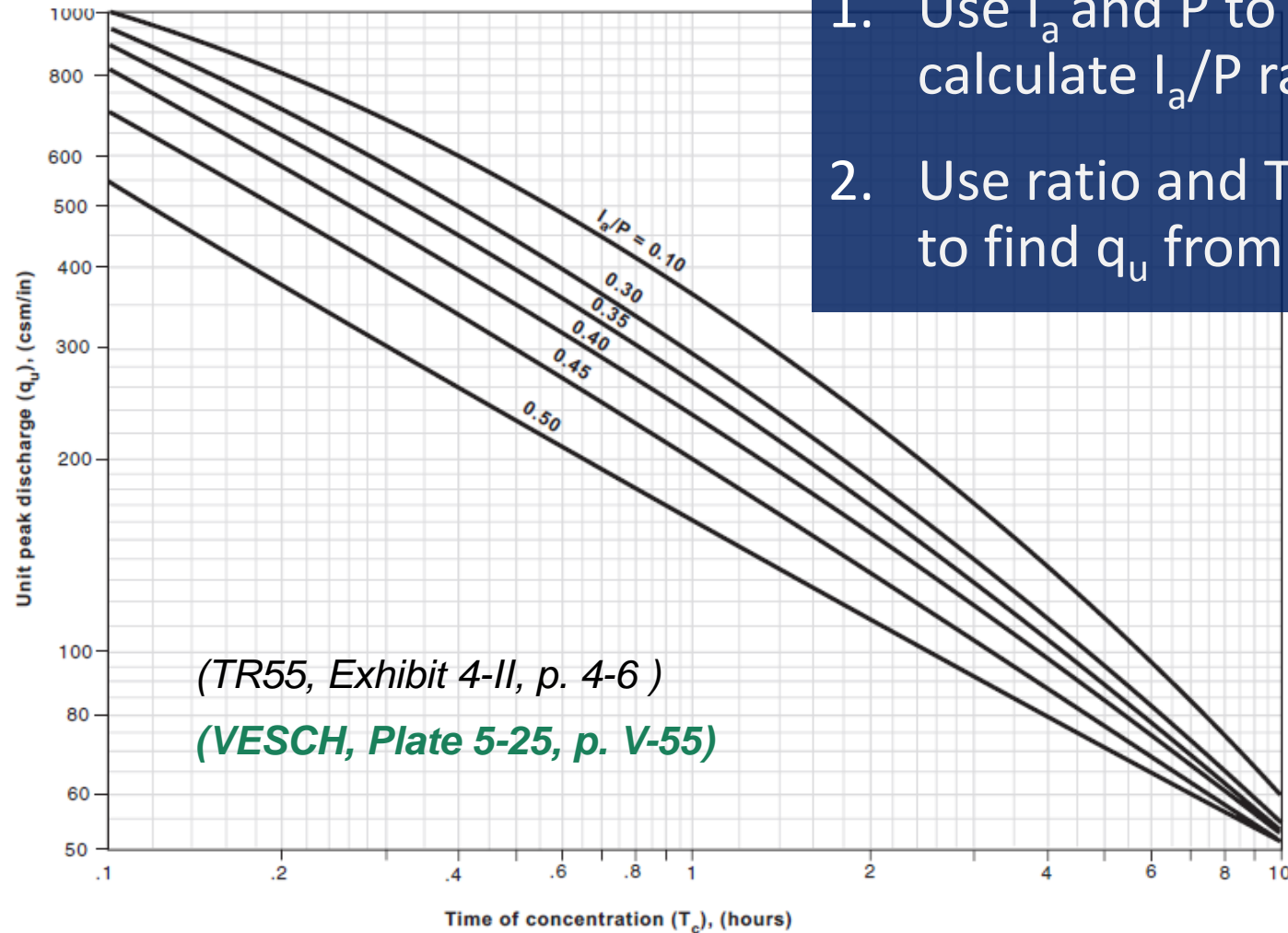
Segment ID	BC	
7. Surface description (paved or unpaved)	Unpaved	
8. Flow length, L	500	
9. Watercourse slope, s	0.04	
10. Average velocity, V (Plate 5-23)	3.2	
11. $T_c = \frac{L}{3600 V}$ Compute T_c	0.04	0.04

Channel flow Segment ID

Segment ID	CD	DE
12. Cross sectional flow area, a	8.0	27
13. Wetted perimeter, P_w	7.6	21.6
14. Hydraulic radius, $r = \frac{a}{P_w}$ Compute r	1.05	1.25
15. Channel slope, s	0.02	0.005
16. Manning's roughness coeff., n	0.08	0.06
17. $V = \frac{1.49 r^{2/3} s^{1/2}}{n}$ Compute V	2.72	2.04
18. Flow length, L	1500	2500
19. $T_c = \frac{L}{3600 V}$ Compute T_c	0.15	0.34
20. Watershed or subarea T_c or T_c (add T_c in steps 6, 11, and 19)		1.13

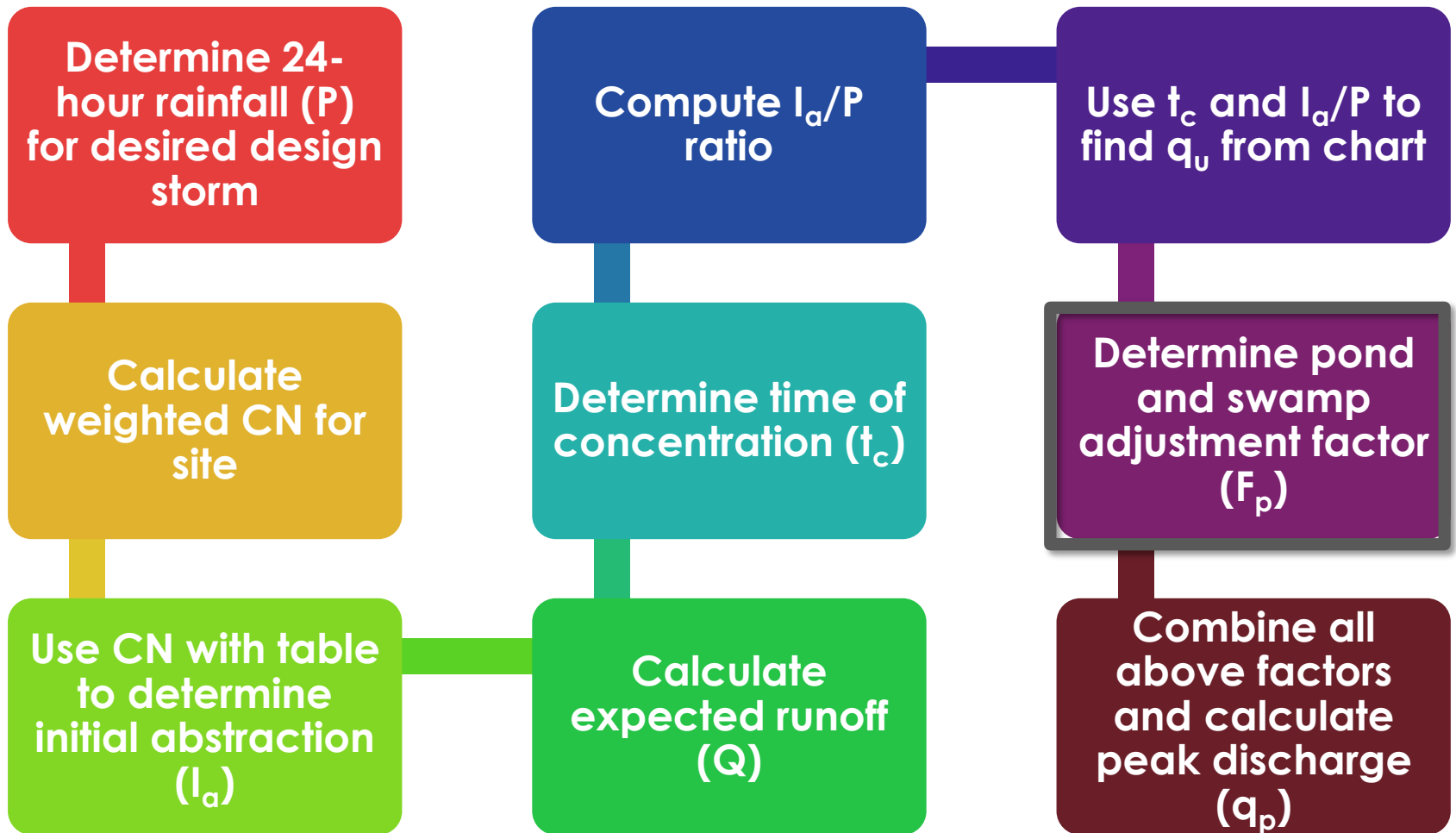
TR-55 Graphical Peak Discharge Method



I_a/P Find q_u Find q_u on chart**Exhibit 4-II** Unit peak discharge (q_u) for NRCS (SCS) type II rainfall distribution

1. Use I_a and P to calculate I_a/P ratio
2. Use ratio and T_c value to find q_u from chart

TR-55 Graphical Peak Discharge Method



Pond/swamp factor (F_p)

$$q_p = q_u A_m Q F_p$$

- Factor needed if ponds and/or swamps scattered throughout watershed, but not on path used to determine T_c

TABLE 5-10

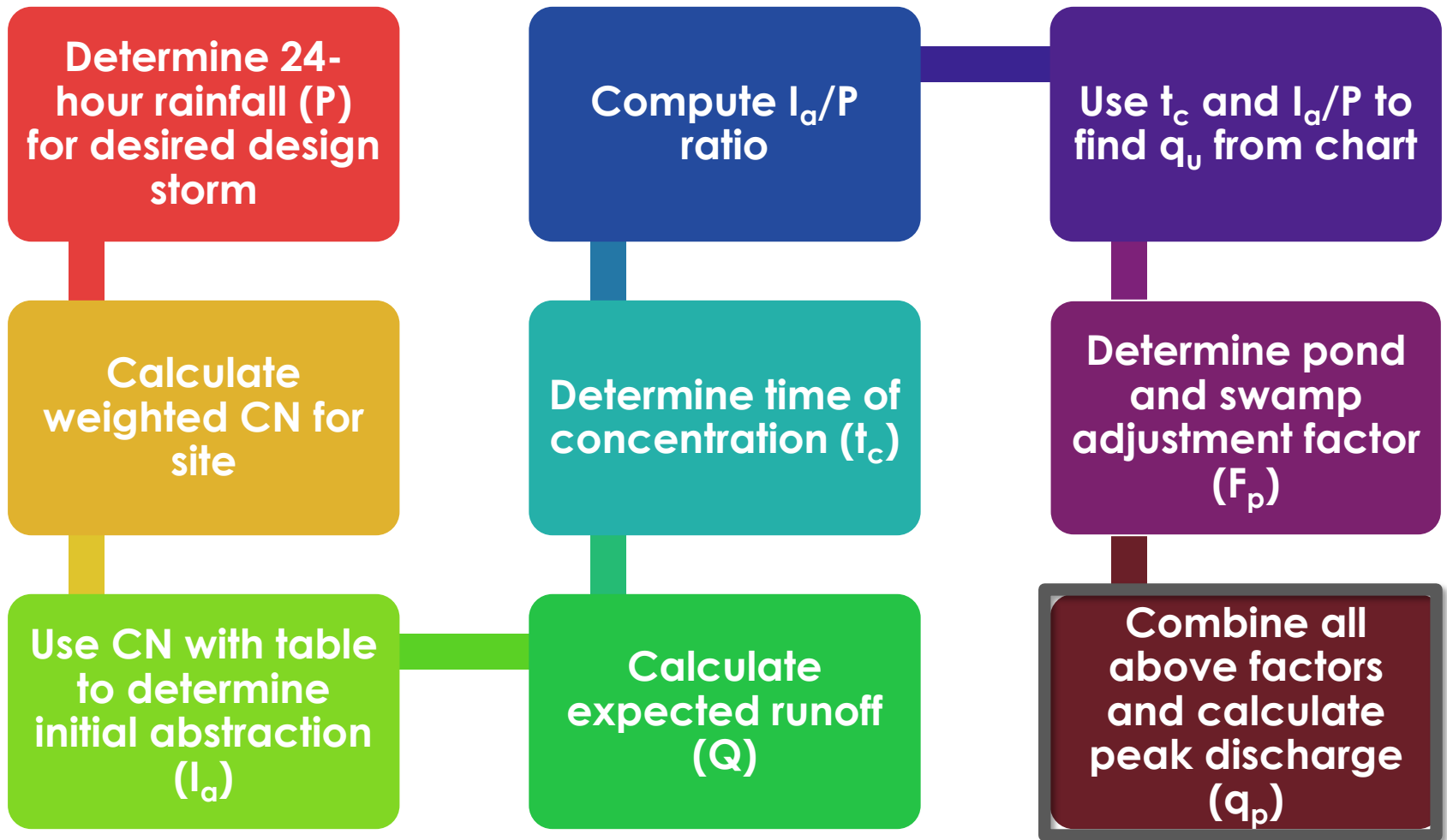
ADJUSTMENT FACTOR (F_p) FOR POND AND SWAMP AREAS SPREAD THROUGHOUT THE WATERSHED

Percentage of pond and swamp areas	F_p
0	1.00
0.2	0.97
1.0	0.87
3.0	0.75
5.0	0.72

VESCH Table 5-10, p. V-65

- Determine percentage of drainage area represented by swamps and/or ponds

TR-55 Graphical Peak Discharge Method



peak
discharge
(q_p)

Calculate peak discharge

$$q_p = q_u A_m Q F_p$$

- q_p (cfs)
- q_u (csm/in) from previous step
- Q (in) from previous step
- A_m (m²) from site plan
- F_p from previous step

Typical worksheet

$$q_p = q_u A_m Q F_p$$

Worksheet 4: Graphical Peak Discharge method

Project <i>Heavenly Acres</i>	By <i>RHM</i>	Date <i>10/15/85</i>
Location <i>Dyer County, Tennessee</i>	Checked <i>NM</i>	Date <i>10/17/85</i>

Check one: ☐ Present ☒ Developed

1. Data

Drainage area $A_m = 0.39$ mi² (acres/640) *Figure 2-6*

Runoff curve number $CN = 75$ (From worksheet 2), *Figure 3-2*

Time of concentration $T_c = 1.53$ hr (From worksheet 3), *Figure 3-2*

Rainfall distribution = *II* (I, IA, II III)

Pond and swamp areas spread throughout watershed = — — percent of A_m (— — acres or mi² covered)

	Storm #1	Storm #2	Storm #3
2. Frequency yr	25		
3. Rainfall, P (24-hour) in	6.0		
4. Initial abstraction, I_a in (Use CN with table 4-1)	0.667		
5. Compute I_a/P in	0.11		
6. Unit peak discharge, q_u csm/in (Use T_c and I_a/P with exhibit 4- — II)	270		
7. Runoff, Q in (From worksheet 2). <i>Figure 2-6</i>	3.28		
8. Pond and swamp adjustment factor, F_p (Use percent pond and swamp area with table 4-2. Factor is 1.0 for zero percent pond and swamp area.)	1.0		
9. Peak discharge, q_p cfs (Where $q_p = q_u A_m Q F_p$)	345		

Worksheets/instructions: TR55 manual:

http://www.wsi.nrcs.usda.gov/products/w2q/H&H/Tools_Models/other/TR55.html.

(also page VESCH p. V-48)

TR55 Windows program:

http://www.wsi.nrcs.usda.gov/products/W2Q/H&H/Tools_Models/WinTR55.html.



Peak Discharge

TR-55: two methods for peak discharge:

- **Graphical Method**
 - Provides **peak discharge + runoff volume**
- **Tabular Method** (*VESCH* p. V-66 to V-83)
 - Provides **peak discharge, runoff volume, and a runoff hydrograph**

Limitations

- Peak discharge method – no hydrograph generated, cannot be used for routing (*basin design*)
- Only one main stream in watershed (*can be applied to multiple stream branches with nearly equal T_c*)
- Watershed must be hydrologically homogeneous (uniform distribution of land use, soils, and cover) – represented by **one CN**

Questions?